Spherical Harmonic Correlation of Pangea and Subducted Slab with Global Seismic Tomography

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A map of continental Pangea, circa 180 Ma, was digitized and expanded numerically in spherical harmonics to degree $l = 8$ (Figure 1). Also, an estimate of the distribution of lithospheric slab subducted since 180 Ma was obtained from plate reconstruction maps, and this area of distribution was digitized and expanded in spherical harmonics to $l = 8$ (Figure 2). The distribution of subducted slab was determined by overlaying successive map reconstructions of the subduction zones from 180 Ma to the present and digitizing the area which fell between the extreme positions of the trenches over that time. Subduction zones appeared to shift direction, backtracking over themselves instead of moving in a constant direction away from their 180 Ma positions. This indicates changes in relative plate motions that were not clearly indicated on the maps used. The areas of Pangea and the subducted slab were digitized to 5° by 5° resolution. The power spectrum of the spherical harmonic expansion for Pangea indicates the dominance of the degree 1 component (Figure 3). The power in degree 3 is most likely the result of the Tethys Sea which cuts into the eastern margin of Pangea. The power spectrum for the expansion of the subducted slab peaks for degrees 2 and 3 (Figure 6). Both of these expansions were correlated with the 11 depth layers (Table 1) of Tanimoto's (1990) global seismic S-wave and Love wave tomography for degrees $l = 1$ to 6. For his tomography, the degree $l = 2$ has the largest power in all layers except shell 5, where $l = 3$ is strongest. Tanimoto is concerned that aliasing may occur for the layers 4 to 6. The correlation between the expansion of Pangea and Tanimoto's tomography is strongest for degree 1 at the bottom of the upper mantle with a correlation coefficient of $r = -0.90$ (Figure 4, see note concerning the sign of correlations). Degree 3 shows a high correlation at the top of the lower mantle with $r = 0.82$ for shell 5 (Figure 5). The high power coefficient at degree 3 for shell 5 in Tanimoto's tomography lends added weight to this correlation. The reversal of sign in the correlation for degree 3 relative to degree 1 is interesting. The correlation between the expansion of the subducted slab and Tanimoto's tomography are strongest for degrees 2 and 3. Degree 2 shows its strongest correlation, $r = -0.79$ at the bottom of the lower mantle; there is a somewhat weaker correlation at the bottom of the lower mantle (Figure 7). Degree 3 has a strong correlation of $r = -0.70$ at the top of the lower mantle (Figure 8). Overall, the correlations of these two degrees indicate a strong tomographic signal from cold, fast material around the 670 km discontinuity.

Previous researchers have reached conflicting conclusions about the path of subducting slab. The primary argument concerns whether the slab cross the 670 km discontinuity. This is a significant point because the answer is strongly dependent on the nature of the boundary, and so would clarify many issues if it were known. Attempts to use seismic ray travel-time anomalies of deep earthquakes to image the dip of the slab further down have not all reached the same results. Fischer et al. (1988) find a near-vertical dip, Zhou et al. (1989) find a sub-horizontal dip at the depth of the 670 discontinuity. Recent discussions of mantle chemistry (Anderson 1989, and Ringwood and Irifune 1988) seem to favor the slab dipping to horizontal, though some slabs might punch through steeply and reach the bottom of the mantle. The problem has also been modeled experimentally in the lab by Kincaid and Olson (1987), and, depending on the density variation across the discontinuity, different regimes of subduction were found – from near vertical dip for no density variation, to horizontal dip for a large density variation. This experimental work generates other useful questions as well, about the significance of dip angle and trench migration. Richards and Engebretson (Fall 1990 AGU Abstract) correlate seismic tomography to sinking slabs, but only for the lower mantle body wave tomographies of Dziewonski (1984) and Hager and Clayton (1988). Their correlation for degree 3 with these tomographies is about the same as the correlations presented here for degree 3. However, their correlations for degrees 1 and 2 are higher. For these degrees, the correlations presented here are highest in the upper mantle and suggest that a significant fraction of the subducted slab is going no deeper than the 670 discontinuity.

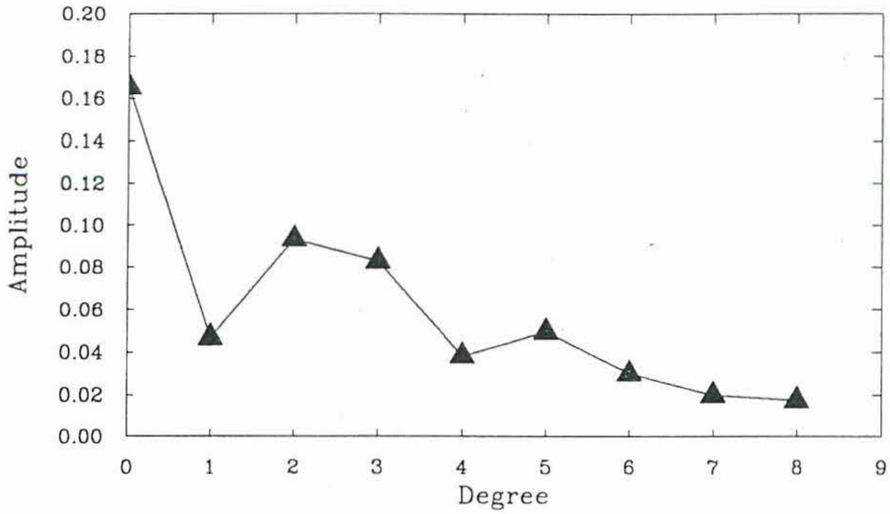

Figure 6: Amplitude spectrum of subducted slab expanded in spherical harmonics to degree $l = 8$. The circum-Pacific slab produces the power at degree $l = 2$, and the Tethyan subduction trench (now the Alpine/Himalayan collision zone) is the source of the power in $l = 3$.

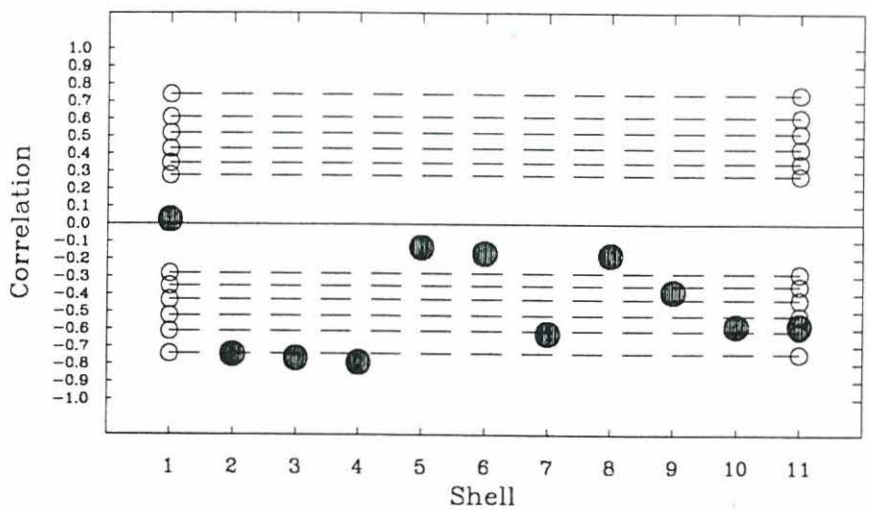

Figure 7: Degree 2 correlation of tomography with subducted slab for shells 1 to 11

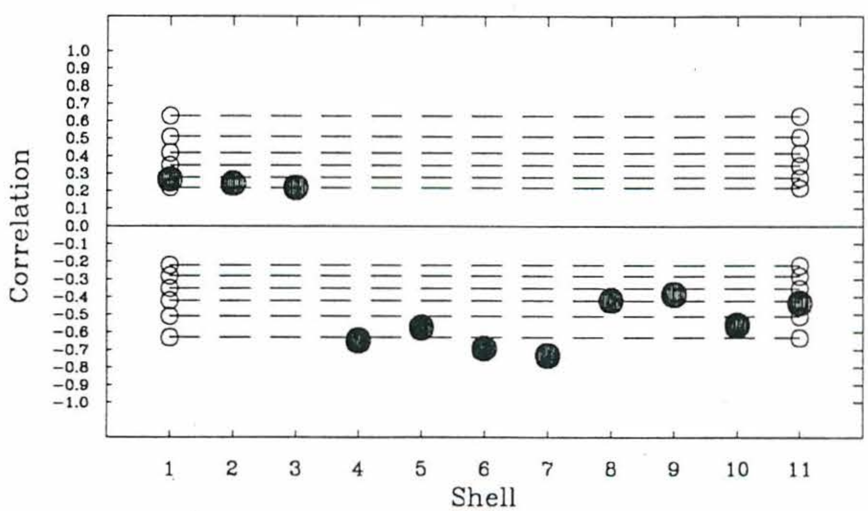

Figure 8: Degree 3 correlation of tomography with subducted slab for shells 1 to 11

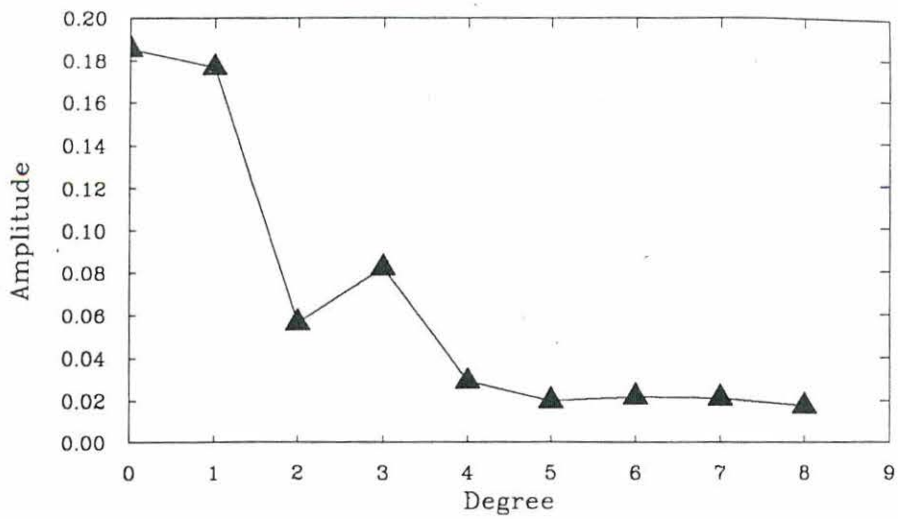

Figure 3: Amplitude spectrum of Pangea expanded in spherical harmonics to degree $l = 8$. The Tethys seaway is responsible for power in $l = 3$

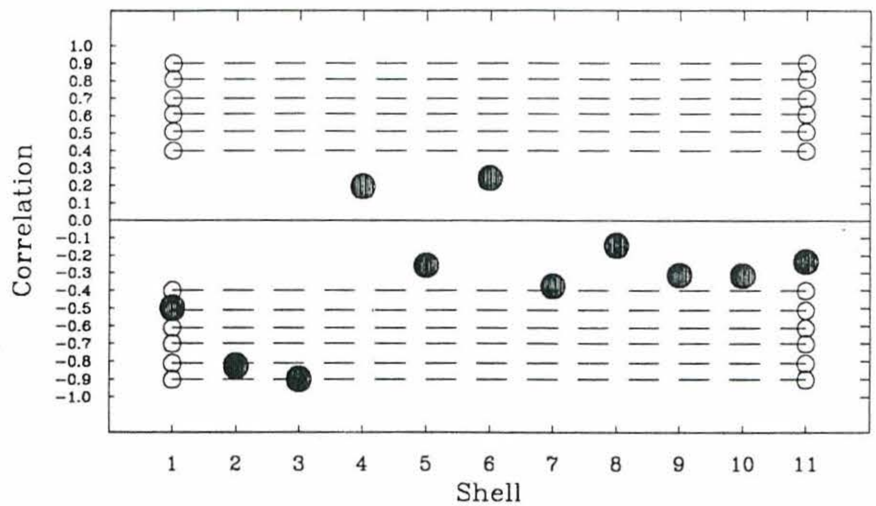

Figure 4: Degree 1 correlation of tomography with Pangea for shells 1 to 11 **Note**: For All Plots, negative correlation values indicate cold, seismically fast mantle material. Dashed lines indicate correlation confidence levels, varying from 50% to 95%

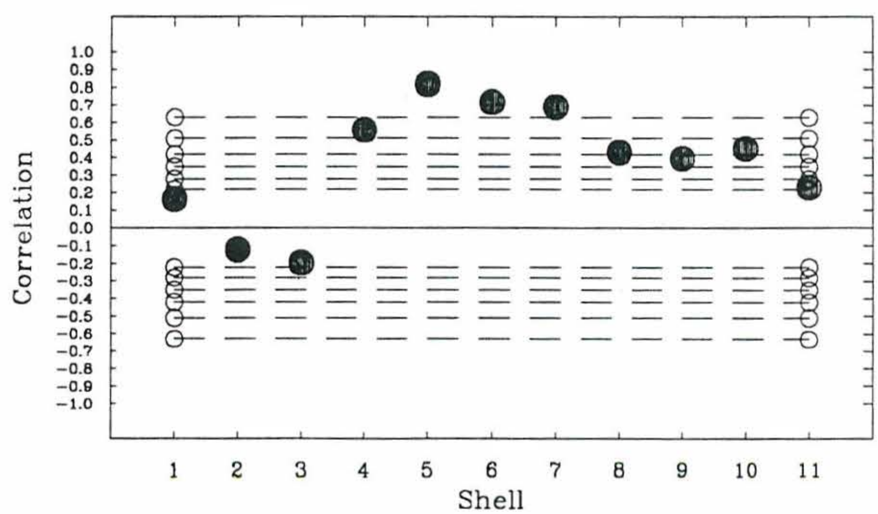

Figure 5: Degree 3 correlation of tomography with Pangea for shells 1 to 11

Shell #	Top	Bottom	Depth
1	6371	6151	220
2	6151	5971	400
3	5971	5701	670
4	5701	5349	1022
5	5349	5087	1284
6	5087	4816	1555
7	4816	4555	1816
8	4555	4283	2088
9	4283	4012	2359
10	4012	3741	2630
11	3741	3480	2891

Table 1: Shells in Tanimoto's Mantle Tomography (in km)

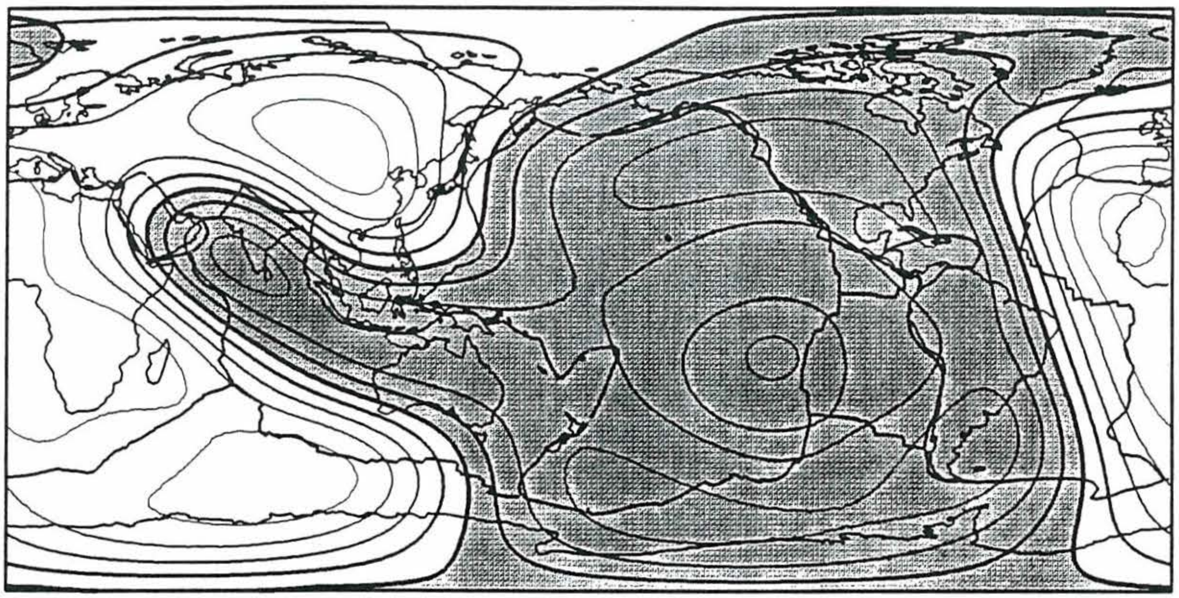

Figure 1: Spherical harmonic expansion of Pangea for degrees $l = 1$ to 8. White areas are positive contours (continental mass of Pangea)

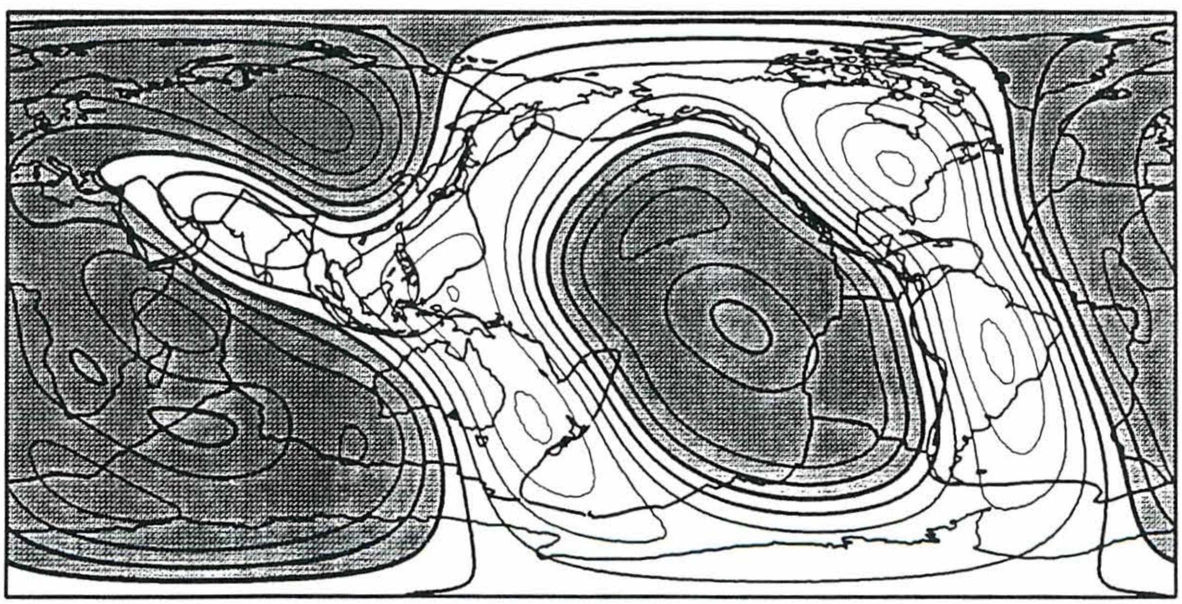

Figure 2: Spherical harmonic expansion of subducted slab for degrees $l = 1$ to 8.

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